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MONTANA URBAN GRADE CROSSING STUDY

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Extract from

MONTANA URBAN GRADE CROSSING STUDY

DEC 6 1974

Prepared by

MONTANA HIGHWAY PLANNING SURVEY

STATE DOCUMENTS

MSE SEP 5 '79

10-3-79

INDEX OF HAZARD

The index of Hazard is a numerical rating of the relative danger, to the public, incidental to the existence and use of each grade crossing. It is designed to indicate the need for the installation of protective devices, if none exist, and only partially the desirability of a grade separation structure.

The method evolved for cumputing the Index of Hazard is based on the assumption that the hazard to the public at any railroad crossing is first, a function of the volumes of vehicular and train traffic, and second, arises from the nature of train movements over the crossing and from the physical conditions existing there. A description of the value and treatment of each element in the formula follows.

In order to establish a maximum and minimum value for the Index of Hazard the three parts of the formula were each assigned a value of ten. This means vehicular traffic weighted as ten, train traffic as 10, and the physical factors at 10. The maximum total obtainable is thus 10 x 10 x 10 = 1000, and the minimum as 1 x 1 x 1 = 1.

VOLUME OF VEHICULAR AND RAILROAD TRAFFIC.

When assigning weights to the various traffic volumes, it did not appear desirable to use a strict progression, but rather to give greater weight to the lower volumes of traffic. A motorist traveling a highway carrying a large volume of traffic is very often warned or stopped by the actions of the car ahead, even though he fails to see the approaching train or warning signal himself. Also, on a highway carrying comparatively little traffic, there is a tendency for the driver to use less care and travel at a higher rate of speed than on a highway carrying more traffic. It is also likely that a motorist familiar with local conditions will approach a crossing carrying heavy volumes of railroad traffic with more care than one having light traffic. With these thoughts in mind, the factors were arranged to give relatively more weight to the smaller volumes of traffic.

PHYSICAL CONDITIONS.

The hazard to the motorist arising from physical conditions at the crossing is considered to be comprised of eleven factors, denoted by F_1, F_2, etc.

While the factor F_1 representing train movements is not dependent upon the physical conditions at the crossing, it is included here for convenience of discussion and treatment.

FACTOR F_1

The factor F_1 represents the danger resulting from the probability of a train and a vehicle arriving at the crossing at the same time. If all drivers were always mentally and physically capable, alert and sober, good judges of distance and speed and inclined to pay attention to the road ahead, and all vehicles were in good mechanical condition, this factor could be ignored. However, a study of accident reports shows this factor to be one of the most important causes of accidents.

The various types of train movements and their operating speeds have been tabulated and a weight assigned to each division selected. Electric operated trains were given a slightly higher hazard rating than steam operated as it was thought this type of train is the more hazardous due to several factors: first, there is no plume of smoke or steam given off which often serves as a warning signal; second, the average electric train, whether freight or passenger, does not make as much noise when running and, third, the electric engines accelerate faster than steam.

FACTOR F_2

This factor represents the hazard arising from restrictions to a clear view of an approaching train. The method of evaluating this hazard presumes: first, that the desirable clear view of the track is directly proportioned to the speed of the fastest train operating on the track and, second, the satisfactory distance from the crossing along the highway from which the desirable clear view of the track is first obtained is proportioned to the distance required to stop a vehicle operated at the maximum normal speed for the highway or street. The maximum normal speeds used in this report are 55 mph on paved trunk highways outside city limits and 25 mph inside the city.

The necessary clear sight distance along the track has been selected as 10 seconds running time for the fastest train operating over the crossing. Table 1 shows the distance traveled in 10 seconds corresponding to speeds from 5 to 85 mph.

The maximum train speed being known, the distance the train travels in 10 seconds is taken from Table 1 and is then marked off along the track on a sketch or map of the crossing. The sight lines are then drawn from the points on the track past the obstruction to the highway for each quadrant. This is illustrated on Figure 1. The train speed is 30 mph and, referring to Table 1, the distance traveled in 10 seconds is found to be 440 feet. This distance is laid off along the track in each direction and the sight lines are drawn. The intersection of the sight lines with the highway determines the points at which the motorist will have his first clear view of the track throughout the distance of necessary clear view. The distance along the highway from the intersection with the sight line is the "Highway Sight Distance" for the particular quadrant.

This is 287 feet for quadrant 1 and 239 feet for quadrant 2 in the illustration.

Table 1. Distance Traveled in 10 Seconds for Various Speeds.

MPH	Distance Traveled in 10 Seconds	MPH	Distance Traveled in 10 Seconds
		45	660
		50	734
10	147	55	807
15	220	60	880
20	293	65	954
25	367	70	1027
30	440	75	1100
35	513	80	1173
40	660	85	1247

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Then, referring to the graph on Figure 2, the "Highway Sight Distance" is located on the lower edge of the chart. Proceed vertically to the intersection with the diagonal line representing the highway speed. The figure opposite this point on the left edge of the diagram is the time in seconds in which the driver must stop his car. Then proceed horizontally to the right to the intersection with the broken line for the vehicular speed. The figure most directly above this point is the factor representing the sight distance for the quadrant. For example, the highway sight as determined for quadrant 1 on Figure 1 is 287 feet. It is necessary to reduce the highway sight distance by 15 feet to provide safe clearance at the crossing. Thus the 287 feet is decreased by 15 feet leaving an adjusted sight distance of 272 feet. Proceeding vertically from the point representing 272 feet on the lower edge of the graph to the intersection with the solid line marked 40 mph (the assumed highway speed) it is found by moving horizontally to the left edge that the motorist has about 4.6 seconds to stop his car. Thence, moving along the time line to the intersection with the broken line marked 40 mph, we find the factormost nearly above this point to be 0.4. This is the sight distance factor for quadrant 1 on Figure 1 for a train speed of 30 mph and a highway speed of 40 mph.

It will be seen that, in the use of the Chart on Figure 2, the travel time does not enter directly into the determination of the factor, but is used in the preparation of the chart. The factor may be found by proceeding vertically from the "Highway Sight Distance" at the bottom of the chart to the solid line, thence to the right to the broken line, representing the vehicular speed, thence vertically to the factor.

The solid diagonal lines on the graph are obtained by plotting distances traveled in feet as abscissa against time in seconds as ordinates for the respective speeds.

The broken lines are designed to incorporate the distance that a vehicle travels while stopping as a factor in the effective sight distance. The minimum stopping distances based on studies by the State Board of Public Roads of Rhode Island, for a car equipped with effective four-wheel brakes on a dry, hard, level highway, free from loose material are listed below in Table 2. The reaction time, that is the time that elapses between the time the driver perceives the necessity for stopping and starts to apply his brakes, is taken as 3/4 second. The distance traveled during the reaction time and the total stopping distance are also listed in Table 2. As the minimum total stopping distance allows no factor of safety, the lines are arranged so that the maximum factor of 0.5 is assigned for the quadrant unless more than twice this minimum distance is available for the motorist to stop his car. A factor of zero is given if the available stopping distance is at least four times the minimum stopping distance. If the available distance is between twice and four times the minimum stopping distance, factors between 0 and 0.5 will be obtained.

Table 2. Stopping Distances in Feet for Various Vehicle Speeds.

MPH	Min. Stopping Distance in feet	+	Reaction Distance Feet	=	Stopping Distance Feet	2 D Feet	4 D Feet
10	4.4		11.0		15.4	31	62
20	17.6		22.0		39.6	79	158
25	28.7		27.5		56.2	112	224
30	39.8		33.0		72.8	145	290
40	70.7		44.0		114.7	229	458
50	110.2		55.0		165.2	330	660
60	159.7		66.0		225.7	451	902

It is thought reasonable to assign the maximum factor for available stopping distances of not more than twice the minimum as described above, as both reaction time and braking distances are taken from records of tests that were probably made under somewhat better conditions than those under which the motorist may be required to stop his car. The factor of safety of four for the point at which the restriction of clear view ceases to be hazardous appears reasonable from these tests.

The method as outlined appears somewhat complicated, but it is described in detail to illustrate the theory involved. In the practical application of the method it is simpler and quicker to obtain the factors from a numerical table which is shown in Table 3. The figures in Table 3 are adjusted to include fifteen feet clearance at the crossing so the Highway Sight Distance may be used without adjustment.

Table 3. Sight Distance Factors for various highway speeds and Sight Distance.

Highway speed mph	Sight Distance Factor					
	/ 0	0.1	0.2	0.3	0.4	0.5
10	77	70	64	58	52	46
15	121	110	100	89	79	68
20	174	159	143	127	111	95
25	236	214	192	170	148	126
30	307	278	249	219	190	161
35	387	350	312	275	238	201
40	475	429	383	337	291	245
45	573	517	461	406	350	294
50	679	613	546	480	413	347
55	794	717	639	561	483	405
60	918	828	738	648	557	467

FACTOR F_3

This factor represents the hazard incidental toinconvenient angles of vision. The angle of vision is the angle between the sight lines and the highway surface as shown on Figure 1. If the motorist can see an approaching train within his normal field of vision, that is, without consciously turning his head, the angle of vision is not considered to be hazardous. The normal field of vision is assumed to be a sector with a central angle of 60° or a deviation of 30° right and left from the center line. For angles of vision greater than those within the normal field progressive weights are assigned.

FACTOR F_4

This factor considers the danger arising from the presence of the railroad tracks at the crossing. The use of multiple tracks increases the hazard. When there is more than one track at a crossing, there is a possibility that standing cars may obstruct themotorist's view of an approaching train. Also, the driver's attention may be deviated to a standing or switching train and away from a train approaching the crossing. The double main line is considered the most hazardous as its very existance indicates the possibility of two moving trains at the crossing at the same time. The main and one passing track is considered less dangerous as the speed on the passing track is usually low and it is used less frequently than the main line. A single main line track is considered less dangerous than one main and one passing track, and is given less weight.

Industry and storage tracks are given smaller weight than a single main line as ordinarily train movements on them are slow and infrequent.

FACTOR F_5

This factor is a consideration of the hazard present because of the alignment of the highway approach.

A tangent on both sides of the track allows the motorist to approach the crossing at any rate of speed he may desire. Curves on the approach force him to slow down to avoid over-running. Since his car is approaching slower, the driver can, of course, stop quicker than if he were traveling on a tangent at a higher rate of speed.

While it is true that curves on the approach may tend to distract the driver's attention from an approaching train to the highway, it is believed that this more than offsets the reduction in speed. With this in mind, the greater weights were assigned to tangents and easy curves, the weight decreasing as severity of the curves increases.

Some thought was given to the condition of highway approaches, that is, whether smooth or rough, etc. It was decided that the condition depended entirely on road maintenance and could be changed at any time and, therefore, should not be considered in a study of this type.

FACTOR F_6

The Factor F_6 represents the hazard presented by intersecting streets within 50 feet of the crossing. The same conditions discussed under factor F_5 are to a certain extent presented by streets intersecting the highway close to the crossing.

Heavy uncontrolled traffic, while tending to distract the motorist's attention from the railroad, will be offset by showing the speed of his vehicle thus increasing the minimum stopping distance and thereby reducing the probability of an accident at the crossing.

Intersecting streets carrying various amounts of traffic, but having no traffic control, are believed to be less hazardous in direct proportion to the amount of traffic carried. That is, the larger the flow of cross traffic, the slower the motorist must travel.

An intersecting street, having traffic control, is believed to present a greater hazard than a street having no control. This is explained in two ways. First, the motorist on the highway, knowing he has the right of way, will speed through the intersection and thus come to the crossing at a higher rate of speed than if he were forced to travel slower to avoid interfering with heavy cross traffic. Second, if the motorist on the highway is stopped by a traffic light, on being released he speeds across the intersection and onto the crossing, building up his speed as fast as possible. If no intersecting streets are present, within the limit specified, it is believed to be safer than if such streets do exist. There is no distractionof the motorist's attention and he is free to watch the railroad for approaching trains and govern his speed accordingly.

The weights assigned to the various parts of Factor F_6 were thus set with the contention that approaching speed at a crossing creates a greater hazard than distraction of attention by other vehicular types.

FACTOR F_7

This factor is indicative of the hazard presented by sun glare at the crossing. The average motorist approaching a crossing looks up and down the track to check train movements; if he is blinded by sun glare, he cannot see an approaching train. During the greater part of the day, sun glare will not be present and, therefore, will not be a hazard. However, in the early morning, and more especially about sunset when traffic is usually heavy, this glare is present and, therefore, should be considered a definite danger.

FACTOR F_8

Factor F_8 is based on the fact that vehicles ascending a grade to a crossing must travel slower than vehicles descending an equal grade. Also, the driver has more control over his car when pulling up a hill than he has when rolling down.

When approaching roads are wet or icy, a car going down hill will have a tendency to skid or slide into the crossing even though the brakes are set and the wheels have stopped turning.

FACTOR F_9

The hazard represented by Factor F_9 could well be termed more of a highway danger than a crossing hazard. It is to be used only when the top of the rails on the crossing are too high for a motorist to see any vehicle approaching from the opposite side. If a motorist cannot see the opposite crossing approach, he may be forced to stop his vehicle on the crossing to avoid collision with the other car.

FACTOR F_{10}

This factor F_{10} represents the hazard incidental to width of crossing. A narrow crossing might be called more of a mental than actual hazard. However, a narrow crossing tends to distract a motorist's attention from the tracks and focus it on the crossing. This condition might also slow the speed of a vehicle and thus balance the hazard, but there is another item to consider. Even though the motorist may be approaching the crossing under restricted speed, he may miss one end of a narrow crossing and drop his car wheels between the rails and stall in the path of an approaching train.

FACTOR F_{11}

Factor F_{11} represents the hazard incidental to a variety of special conditions that may divert a motorist's attention from an approaching train and still not slow the speed of his vehicle. Included here are such items as scenic or other attractions, switching trains on nearby tracks that do not cross the road, heavy numbers of pedestrians on the highway, etc.

The calculation of the Index of Hazard as outlined above produces an indication of the probability of accidents, but does not consider the probable

severity of those accidents. Therefore, the inclusion of a supplementary factor to represent the seriousness of these accidents is thought advisable.

It is impossible to devise any accurate method of determining the probable percentage of fatalities among accidents, but it is thought that any reasonable measure of this will be of considerable value if used in conjunction with the Index of Hazard in selecting sites for crossing protection.

The product of the Index of Hazard and the "Accident Severity Factor, FA", is thought to be a reasonable indication of the probable loss to society, incident to the existence and use of an unprotected grade crossing.

Present protection existing at the crossing is not considered in the computation of the Index of Hazard. The method is designed to indicate the relative need for protective devices so that a tabulation of the three factors - Index of Hazard, Probable Severity of Accident and Existing Protective Devices for each crossing will indicate which crossings need protection or additional protection.

INCONSISTENT

No consideration has been given to accidents because they have been so few at most crossings that they appear to be distributed by chance rather than according to the hazard existing at the crossing.

The weights assigned the various factors and the method of computing the index and the probable severity of accident numbers is described in Part II.

INDEX OF HAZARD FACTORS

The index of hazard is computed from the following equation:

$$1\ H = V \times T\ (F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7 + F_8 + F_9 + F_{10} + F_{11})$$

The first step is to ascertain the factor V representing the volume of vehicular traffic, this is obtained from Table 1.:

Table I. Factor for volume of Vehicluar Traffic

Factor V	Average Number of Vehicles (24 hr. Av.)
1	1 to 50
2	51 to 125
3	126 to 300
4	301 to 625
5	626 to 1100
6	1101 to 1700
7	1701 to 2500
8	2501 to 3600
9	3601 to 5000
10	5001 or more

This factor V has a maximum weight of 10.0

The factor T, representing the volume of railroad traffic is obtained from Table II.:

Table II. Factor for Volume of Railroad Traffic

Factor T	Number of Trains (24 hr. Av.)
1	1 or 2
2	3 to 5
3	6 to 9
4	10 to 15
5	16 to 24
6	25 to 35
7	36 to 48
8	49 to 63
9	64 to 80
10	over 80

This factor T has a maximum weight of 10.0

The factor F_2 is indicative of the inherent hazard present at any crossing because of the various types of train movements.

The weights for this factor are fixed as follows:

Electric interurban trains operating at 25 mph or less	0.5
" " " " " 25 " " more	1.0
Steam passenger trains operating at 25 mph or less	1.0
Electric " " " " 25 " " "	2.0
Steam freight trains operating at 25 mph or less	2.0
Electric " " " " 25 mph or less	2.0
Steam passenger trains operating at 25 - 45 mph	2.0
Electric freight trains operating over 25 mph	3.0
Steam " " " " 25 mph	3.0
Steam passenger trains operating at 46 - 65 mph	3.0
Electric " " " " 46 - 65 "	4.0
All trains operating over 65 mph	4.0

Maximum weight for this factor is 4.0

If several different types of train movements occur over the same crossing, the weight will be on an adjusted average of the weights of the various types of train movements: the relative volume of each being considered. For example, a crossing has 4 steam freight trains operating at 35 mph, 2 steam passenger trains operating at 60 mph, and 2 electric passenger trains operating at 60 mph. The adjusted weight for factor F_1 would be:

$$F1= \frac{(4 + 2) + (2 + 3) + (2+ 4)}{4 + 2 + 2} = 2.\overset{75}{\boxed{12}}$$

Factor F_2 is the sight distance factor representing the danger incidental to restricted vision.

To obtain the sight distance factor, first obtain from Table III. the distance that the fastest train operating over the crossing will travel in 10 seconds.

Then on a map or sketch of the crossing, this distance is scaled along the track from the center of the lane carrying the traffic over the crossing. On multiple lane roads, such as city streets, the measurements are taken from the center of the approaching lanes. If there are two main line tracks, the distance traveled in 10 seconds by the train should be marked on the track for the trains approaching the crossing.

Sight lines are drawn from the points on the track to the center line for the traffic approaching the crossing just clearing the obstructions to the line of sight. The distance called "Highway Sight Distance", from the point the sight line intersects the highway to the crossing is measured for each quadrant. This operation will be clarified by refering to the sketch of a hypothetical crossing on Figure 1.

The highway sight distance having been found, Table IV, is entered on the line corresponding to the highway speed over the crossing and the number on that line that is nearest to the highway sight distance for the particular quadrant is located. The sight distance factor above the number is the weight to be assigned

for the particular quadrant. The sum of the weights for the four quadrants is the factor F_2.

Any obstruction that is so small that less than one-half of a railroad car is obscured from all points on the highway is not considered an obstruction. If the obstruction is large enough to obscure a part of the train from some point on the highway but a reasonably unlimited clear view of the track is available behind the obstruction one-half the weight is assigned that would be obtained if a clear view behind the obstruction were impossible.

Table III. Distance Traveled in 10 Seconds for Various Speeds

MPH	Distance traveled in 10 Seconds	MPH	Distance traveled in 10 Seconds
10	147	50	734
15	220	55	807
20	293	60	880
25	367	65	954
30	440	70	1027
35	513	80	1173
40	587	85	1247
45	660		

Table IV. Sight distance factors for Various Highway Speeds and Highway Sight Distances.

Highway Speed	Sight Distance Factor					
MPH	0	0.1	0.2	0.3	0.4	0.5
10	77	70	64	58	52	46
15	121	110	100	89	79	68
20	174	159	143	127	111	95
25	236	214	192	170	148	126
30	307	278	249	219	190	161
35	387	350	312	275	238	201
40	475	429	383	337	291	245
45	573	517	461	406	350	294
50	679	613	546	480	413	347
55	794	717	639	561	483	405
60	918	828	738	648	557	467

Maximum weight for factor F_2 is 2.0

The factor F_3 represents the hazard incidental to inconvenient angles of vision. The angle of vision is the angle between the sight line and the center of the lane carrying the traffic to the crossing as shown on Figure 1. In the event that the view is unobstructed in any quadrant, the distance that a motor vehicle will travel in 10 seconds is taken from Table III, and this distance is laid off to the point previously determined on the railroad track.

The weights for the various angles of vision are given in Table V. The sum of the weights for the four quadrants is the factor F_3.

Table V. Weights for Various Angles of Vision

Angle of Vision	Weights
0° to 30°	0
31° to 45°	0.05
46° to 60°	0.10
61° to 75°	0.15
76° to 90°	0.20
Over 90°	0.25

The maximum weight for factor F_3 is 1.0

Factor F_4 represents the hazard incidental to the prexence of railroad tracks. The values assigned to this factor increase as the number of tracks increase. The weights used are given in Table VI.

Table VI. Weights for Various Track Layouts

Track Layout	Weight
Single track	0.1
One main and one passing	0.2
Two main line tracks	0.6
Additional for each track in addition to those above	0.02

The maximum weight for factor F_4 is 0.8

Factor F_5 is indicative of the hazard incidental to the alignment of the highway approaches. Weights assigned to the various parts of this factor are given in Table VII.

Table VII. Weights Assigned for Various Highway Approaches

Highway Approach	Weight
Tangent both sides	0.6
Tangent one side, curve on other with external 20° to 60°	0.5
Tangent one side, curve on other with external over 60°	0.4
Curve both sides with externals 20° - 60°	0.3
Curve both sides, with one external 20° - 60° external on other side over 60°	0.2
Curve both sides with externals over 60°	0.1

The maximum weight for factor F_5 is 0.6

For this purpose, a curve having an external of less than 20° is considered the same as a tangent in the alignment of highway approaches.

Note: The external angle of a curve is equal in degrees to the change in the course or bearing of the road because of the curve.

Factor F_6 is for the intersecting streets within 50 feet of the crossing. Weights assigned the divisions of this factor are given in Table VIII.

Table VIII. Weights assigned for Various Intersecting Street Conditions

Intersecting Street	Weight
Intersecting street with busy driveway from service station or other business establishment	0.1
Intersecting street carrying low volume of traffic - No traffic control	0.2
Intersecting street carrying moderate volume of traffic - No traffic control	0.3
Intersecting street carrying heavy volume of traffic - No traffic control	0.4
Intersecting street carrying any volume of traffic and having traffic control such as stop signs, traffic lights, etc.	0.5

The maximum weight for factor is 0.5

Factor F_7 represents the hazard presented by sun glare on the crossing approaches. Weights assigned for the two parts of this factor are given in Table IX.

Table IX. Weights Assigned for Various Sun Glare Conditions

Condition	Weight
Sun glare on one approach, or slight on both	0.1
Sun glare on both approaches	0.2

The maximum weight for factor F_7 is placed at 0.2

The factor F_8 is indicative of the hazard set up by the gradient of the approach. This is divided into two parts having equal but opposite weights; one part for ascending grades into the crossing and the other for descending grades.

The weights assigned the divisions of this factor are given in Table X.

Table X.. Weights assigned for Various Approaching Grades

Grades	Weight
0% - 9% ascending or descending	0.05
10% - descending grade	0.10
10% - ascending grade	0.00

Factor F_9 is representative of the hazard caused by restricted sight distance on the crossing. It is to be used only when the top of the rails are so high above the approaching grade that a motorist can not see a vehicle coming from the other side. Weights assigned are given in Table XI.

Table XI. Weights assigned to Sight Conditions on Crossing

Sight Distance on Crossing	Weight
Blind	0.2
Open	0

The maximum weight for factor F_9 is 0.2

Factor F_{10} represents the hazard created by a narrow crossing. The more narrow a crossing, the more the motorist concentrates on it at the expense of looking for approaching trains. Weights assigned are given in Table XII.

Table XII. Weights Assigned for Various Crossing Widths

Width of Crossing	Weight
16'	0.2
24'	0.1
Over 24'	0

The maximum weight for factor F_{10} is 0.2

Factor F_{11} is assigned to any special conditions that might arise on various crossings.

A maximum weight of 0.3 may be assigned for these special conditions that tend to distract the motorist's attention. Such as scenic or other attractions, switching trains on nearby tracks that do not cross the road, large numbers of pedestrians on the road, etc.

Calculation of Index of Hazard

1 H = V x T x F

1 H = Index of Hazard
V = Volume of Vehicular traffic
T = Volume of Railroad traffic
F = Sum of all factors from 1 to 11

The lowest value that can be obtained is 1 x 1 x 1 = 1

The highest value that can be obtained is 10 x 10 x 10 = 1000

All calculations incidental to the computation of the index of the hazard will be done on the computation sheet, a copy of which is attached. The computation sheet will be attached to the other information sheets for each crossing.

Accidental Severity Factor, FA, is used as a supplementary factor in conjunction with the Index of Hazard to obtain a value designated as "Probable Severity of Accident". The values assigned to this factor are given in Table XIII.

Table XIII. Weights Assigned for Various Speeds as Accident Factor

Maximum Train Speed Plus ½ Maximum Normal Vehic. Speed	Weight
50 or more	10
40	8
30	6
20	4
10	2

To obtain "Probable Severity of Accident" Value
1 H x FA = PSA

HPS Crossing No. ____________

City ______________________________
County ______________________________
Street Name ______________________________
Type of Pavement ______________________________
Width:-Property Line to Property Line ____________
-Curb to Curb or Traveled Way ____________
Sidewalks at Crossing: ( ) No
( ) One side ( ) Both sides
Distance along railroad to nearest grade separation if within 2500 feet ______________________________
Distance on each side of railroad to first intersecting street within 600 feet of crossing: to left: ___ To right _____ 1/

Reference to Grade Crossing Map No. ____________
Railroad ______________________________
Railroad Operating Division or Branch ____________
Railroad Crossing Number ____________
Valuation Section and Station Number ____________
Number and Kind of Tracks ____________
_______ Main _______ Passing ______ Industrial or Storage
Construction Material of Crossing ____________
Crossing Illuminated (Street lights within 100' of nearest main track): ( ) No ( ) One side ( ) Both sides
Highway-Highway intersection within 300' of Crossing
( ) No ( ) One side of R.R. ( ) Both sides of R.R.
Type of Soil Adjacent to Crossing ____________

Protection 2/			
No Warning Signal		Lights and Bells	
Signs only		Wigwag	
Bells		Wigwag and Lights	
Lights Stationary		Wigwag and Bells	
Lights Flashing		Wigwag Lights &Bells	
Lights Stop and Go			

Gates or Barriers 3/		
Manual	Automatic	
( )	( )	Gates
( )	( )	Barriers
( )	( )	Chain or Cable
( )	( )	Other Devices-describe
		______________________________

( ) Gates not classified

Place letter "R" in space here provided if signs are equipped with reflector buttons ____________.
Watchman: No ( ) Yes ( ) Hours on Duty: From __________ To __________ Total Hours __________.
If gates are operated from a tower and no watchman on ground, explain here ______________________________
General Direction of Survey (along line of railroad) ____________
Grade and Alignment of Highway Approaches: 4/
To Left of Railroad-Maximum Approach Grade __________% Alignment ____________
To Right of Railroad-Maximum Approach Grade __________% Alignment ____________
Angle of Crossing (show the smaller angle at intersection) ____________

CLEAR SIGHT DISTANCES ALONG RAILROAD FROM POSITIONS ON CENTER LINE OF STREET AS STATED BELOW 5/

Distance of Observer from Crossing 6/	At left of R. R. facing crossing				7/ At right of R. R. facing crossing			
	To Left:	Obstruction	To Right:	Obstruction	To Left:	Obstruction	To Right:	Obstruction
300 feet	_____ft.	________	_____ft.	________	_____ft.	________	_____ft.	________
200 feet	_____ft.	________	_____ft.	________	_____ft.	________	_____ft.	________
100 feet	_____ft.	________	_____ft.	________	_____ft.	________	_____ft.	________
positions on highway (within 100' of crossing) for maximum clear view 6/	Looking to left: Distance from track ______ft. Clear view along R.R. ______ft.		Looking to right: Distance from track ______ft. Clear view along R.R. ______ft.		Looking to left: Distance from track ______ft. Clear view along R.R. ______ft.		Looking to right: Distance from track ___ft. Clear view along R.R. ___ft.	

(Over)

hours

Total Vehicles ______ Pedestrians ______

Note here any special factor contributing to abnormal highway traffic ______

1/ Left and Right to be determined according to the general direction of surveyalong the railroad.

2/ Show in proper column the letters "S", "D", "CO" or "CG" to denote whether the installation is Single, Double, Center (overhead) or Center (ground), respectively: or if there are no signals check thus ✓ opposite "No Warning Signal."

3/ Check items applicable, using letter "S" if gates etc., are on one side of crossing only, and letter "D" if on both sides.

4/ Grades to be recorded are the maxima within 300 feet of crossing. Alignment to be described as "Tangent", "Moderate Curve", or "Sharp Curve" occurring within 600 feet of crossing.

5/ Record on back of sheet sight distances on other important streets intersecting within 300 feet of crossing.

6/ Distances to be measured from center of nearest main track. No observation to be taken closer than 15 feet from center of the nearest main track.

7/ These directions are to be indicated in relation to the direction in which the field party is proceeding along the railroad.

Obstructions to be briefly described: e.g., house, store, depot, shanty, trees, bushes, R.R. Cut, etc. Use check (✓) where clear sight is 2000' or more.

8/ Where more than single 15-minute peak period counts are taken, the record should be given by half-hour periods, using back of sheet or a special form if preferred.

9/ Show whether a.m. or p.m. and strike out word not applicable.

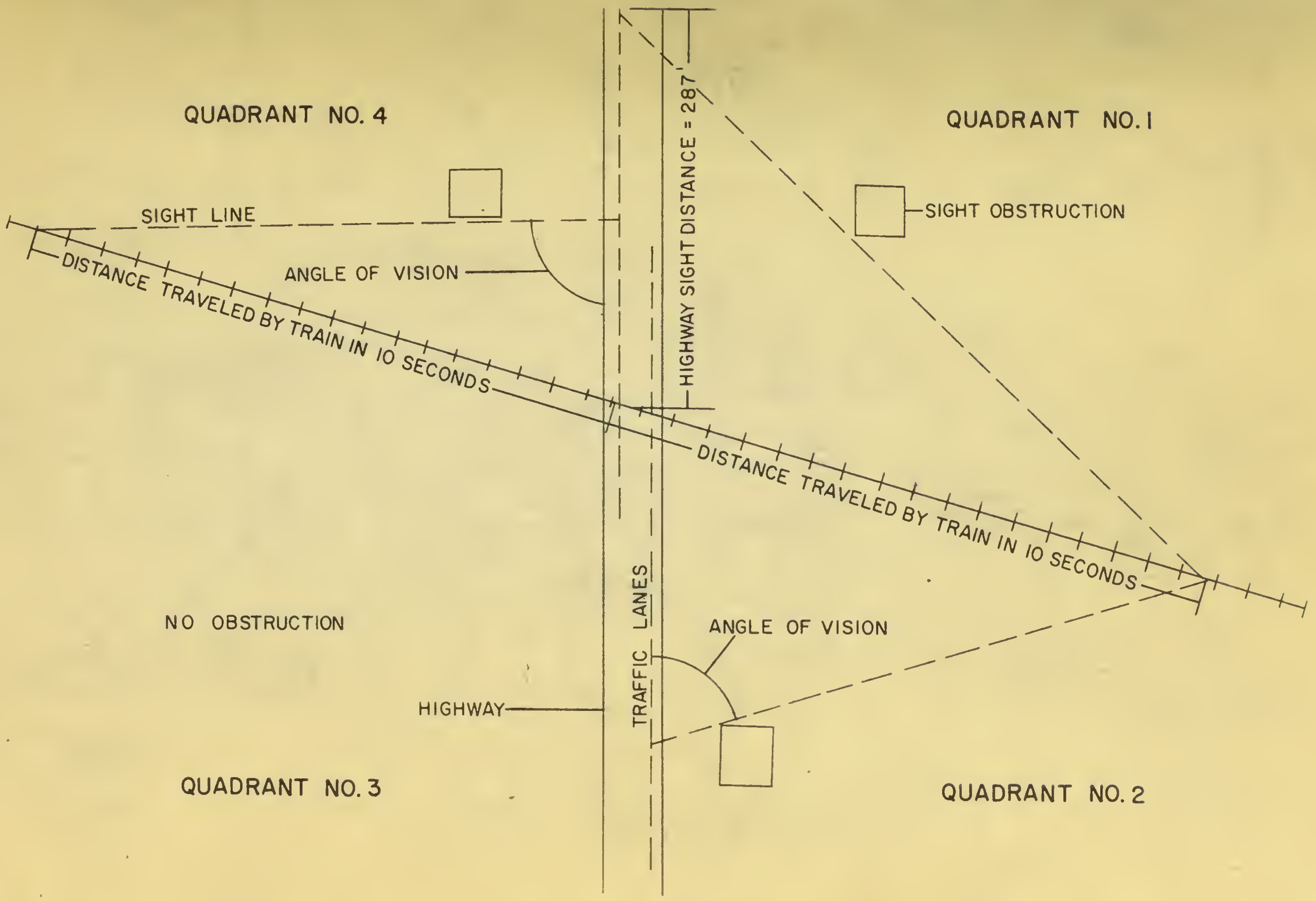


FIGURE I

Scale 1" = 100'

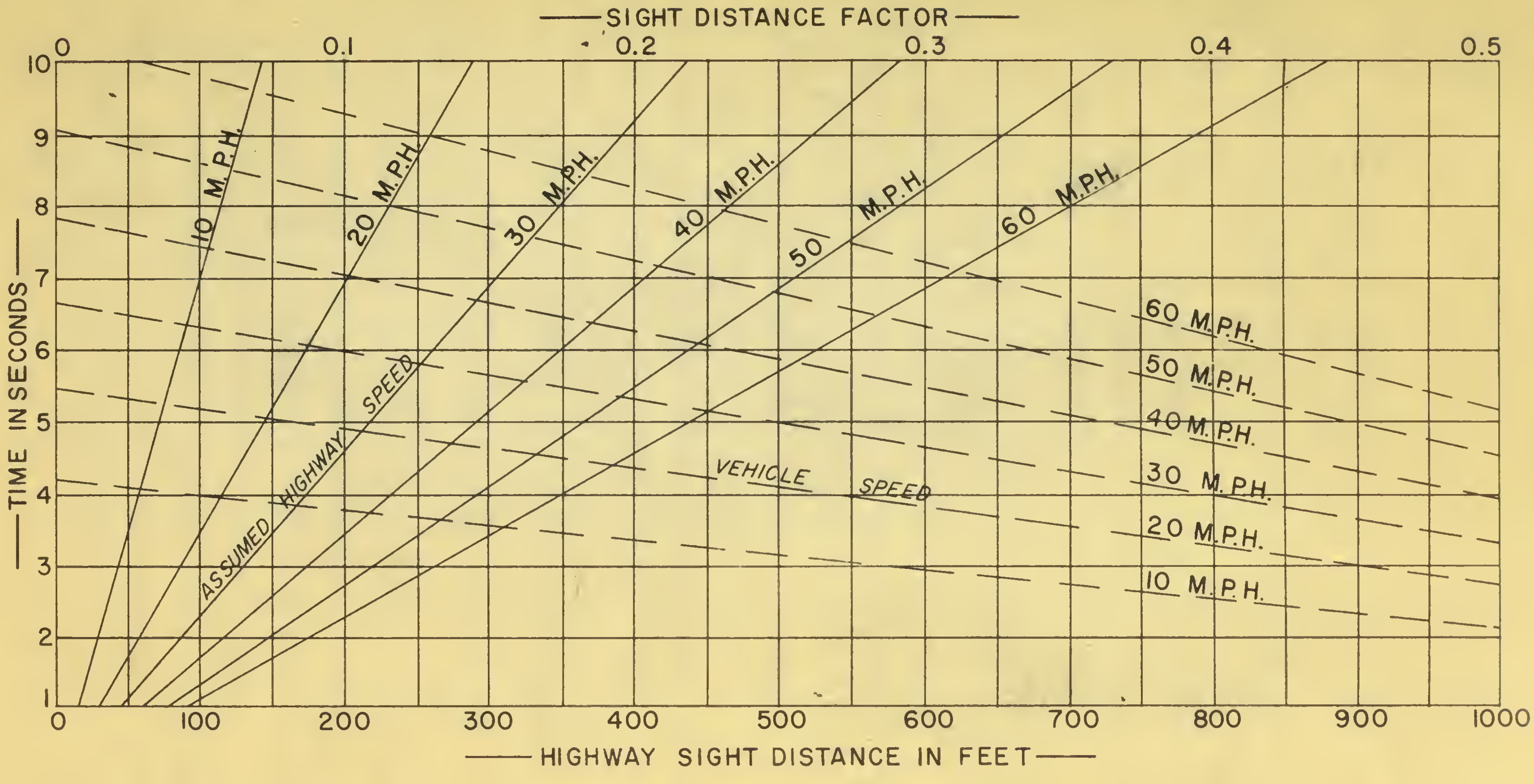

SIGHT DISTANCE FACTOR
0
0.1
0.2
0.3
0.4
0.5
TIME IN SECONDS
10
9
8
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700
800
900
1000
HIGHWAY SIGHT DISTANCE IN FEET
10 M.P.H.
20 M.P.H.
30 M.P.H.
40 M.P.H.
50 M.P.H.
60 M.P.H.
ASSUMED HIGHWAY SPEED
60 M.P.H.
50 M.P.H.
40 M.P.H.
30 M.P.H.
20 M.P.H.
10 M.P.H.
VEHICLE SPEED

FIGURE 2

Copied from: The Traffic Digest & Review, ITE
June, 1956

TO AND FROM SCHOOL

HOW MUCH PROTECTION? - HOW MUCH EDUCATION?

Educators and traffic authorities meeting in joint session during both the 1954 and 1955 National Safety Congress participated in group discussion on traffic problems of young people going to and coming from school. Mainly these representatives wanted to decide: how much protection should be afforded the youngsters, how much must they be educated to protect themselves?

Represented in the two-year project were the U.S. Office of Education, the American Automobile Association, the Association of Casualty and Surety Companies, the Institute of Traffic Engineers, the National Association of Independent Insurers, the National Association of Automotive Mutual Insurance Companies, the National Commission on Safety Education of the NEA, the National Safety Council, the U.S. Bureau of Public Roads, the International Association of Chiefs of Police, and the National Congress of Parents and Teachers.

As a result of general discussion during the 1954 sessions, those meeting in 1955 made an effort to agree upon some principles to assist educators, engineers and police in solving the to and from school traffic problems. The 1955 group accepted the principles below as reported by discussion leader J. Stannard Baker, director of research, Traffic Institute, Northwestern University, Evanston, Ill.

Providing Gaps in Traffic

1. Where natural gaps in vehicular traffic are not great enough or frequent enough to permit groups of children to cross streets in a safe and orderly manner on the way to and from school, traffic authorities should take steps to provide such gaps or some other means of crossing the street, such as overpasses.

2. The need for providing such gaps should be judged on the basis of objective studies on vehicle and pedestrian traffic volumes with recognition of established warrents for this purpose. Priorities should be given to locations

involving greatest potential conflict between crossing children and passing vehicular traffic.

3. Children should be required to go a reasonable distance (for example one-eighth mile) to utilize crossings where existing gaps are adequate, rather than expecting traffic authorities to establish special gaps at additional locations.

4. School authorities and traffic authorities should cooperate in selecting routes for children going to and from school which will subject the children to minimum risks and require minimum outlay for creating special gaps in traffic for them. Schools should, at the beginning of each school year, instruct children carefully in the use of these routes, inform parents of the safest routes and persuade parents to cooperate fully in getting children to use them.

5. School safety patrols should not be permitted to direct traffic for the purpose of creating special gaps. Special crossing guards should be permitted to do so only when individually authorized by the police department after being qualified with respect to physical ability, character and suitable training.

Educational Functions of Persons Supervising School Crossings

1. No person assigned to supervise children at a school crossing or to create special gaps in vehicular traffic at such places should encourage or permit children to cross in any manner which would be an undesirable practice at any unsupervised crossing.

2. In addition to directing vehicle traffic to create gaps for children and indicating to children when to use gaps, police and other adult crossing guards should encourage children to behave as they have been instructed to in using the streets especially in crossing. They should do this by continually reminding the children of proper behavior through such admonition as, "Walk, don't run," and "Now, look to the right." If necessary the child should be restrained.

If, by chance, the adult assigned to the crossing does not know what practices

have been taught the children, he should limit his activity to directing traffic until he has become familiar with the details of the school program for developing safe traffic habits in children.

3. School authorities should undertake systematically, usually in classes, to see that every child understands exactly what behavior is expected of him on the streets, not only in going to and from school but also at other times and places.

4. Police departments should instruct officers assigned to school crossing duty and other adult crossing guards not only in methods of directing traffic, but also in methods recommended by school authorities to develop in children proper habits of street use so that they may help on the street in giving children the necessary practice. Representatives of schools may be invited by the police to assist in such instruction.

Police and other adults assigned to school crossings should visit the school to determine exactly what is being taught the children there about use of streets, and how school safety patrols are being instructed to operate. If instruction is given in classes, these classes should be visited by the adults assigned to crossings at these schools. Schools may invite such crossing guards or other police representatives to assist in such instruction.

Instruction of adults assigned to school crossings should be a police responsibility; instruction of children in crossing should be a school responsibility.

5. Adults assigned to school crossings and school safety patrols should not relieve chilodren of all responsibility in crossing streets by leading them across by the hand, or herding them into regimented groups. Overprotection retards development in the child of safety habits and responsibility for his own safety. It may keep him out of trouble at the school crossing, but it will not prepare him to meet crossing situations effectively elsewhere.

6. The objective of both the school training program and the supervision

of the child in crossing streets should be the same: to develop in the child at the earliest possible age the ability to take care of himself and the feeling of responsibility for doing so that will protect him not only at school crossings but wherever he goes throughout the rest of his life.

REPORT ON WARRANTS FOR TRAFFIC OFFICERS AT SCHOOL INTERSECTIONS

BY THE JOINT COMMITTEE OF THE INTERNATIONAL ASSOCIATION OF CHIEFS OF POLICE AND THE INSTITUTE OF TRAFFIC ENGINEERS.

In its Progress Report for 1946, the Committee listed five conditions which might warrant traffic officer control at non-signalized intersections and five more where they might be warranted with signals. Because establishing specific warrants for all of these conditions was beyond the resources of the Committee, efforts were concentrated on the first condition listed, namely school crossings.

Analysis of the problem showed that fundamental questions of the functions of police at school intersections were involved and could not be resolved without considering the responsibilities of schools and parents. On the basis of conclusions reached concerning the duties of police at school crossings, and in the light of the observations, experience and opinions of committee members and others consulted, specific warrants were drawn up. They are summarized on the next page and the reasoning back of them is outlined in the following pages.

All members of the committee contributed ideas, suggestions and criticisms. A number of them met with the Chairman in Chicago and Cincinnati to discuss the preliminary report. In addition Dr. Wayne Hughes and his associates, Vivian Weedonand Marion Telford, of the School and College Division of the National Safety Council, offered helpful comments and criticism which are greatfully acknowledged.

The concensus of the Committee is embodied in these:

RECOMMENDATIONS

1. The warrants should be approved at once by the I.T.E. and the I.A.C.P. but on a tentative basis so that some .guide, even though not fully perfected, will be available immediately.

2. This report should be sent to other interested organizations and individuals, that the ideas in it may be subjected to consideration from more angles.

3. A joint Committee for developing such warrants should be continued in 1948 and possibly subsequent years. Such a Committee should consider further refinements in these warrants as well as warrants in other conditions.

4. A succeeding Committee should be instructed to request that these warrants be compared with existing practices in a number of cities, not to determine whether they represent such practices, but to find mout how they would function if applied. It would be useful in refining these warrants if a school crossing survey could be made in some community of medium size. After wider scrutiny and practical application, these warrants should be adjusted, if necessary, and final approval secured.

SUMMARY

An officer is usually warranted at a school crossing when three conditions are fulfilled:

1. Adequate natural gaps in traffic for crossing on foot are not sufficiently frequent for safety. For the various street widths tabulated below, adequate gaps ordinarily appear when the traffic volume in vehicles per hour is less than that indicated.

Street Width (Feet)	Maximum Traffic Volume Permitting Adequate Gaps for Walking Across	
	Single Person or Small Group	Large Groups 30 to 40 Children
25	1000	400
30	750	350
40	500	250
50	350	200
60	250	150
80	150	80
100	80	50

2. The total cost of creating adequate gaps in traffic cannot be done more economically by properly designed traffic signals, by school employees or others especially deputized for this purpose.

3. No other intersection in the community is known where police control of traffic would protect children at a lower cost per child.

4. The product of the traffic volume in thousands of vehicles per hour on the street while it is being crossed multiplied by the number of children crossing on their way to or from school exceeds 30.

Traffic officers are not warranted at school crossings to guard children against their own carelessness or to train them to cross safely; these are not police functions. However, if officers are assigned to school crossing duty, they should cooperate in guarding and training children especially the very young ones.

DISCUSSION

Demand for Traffic Officer Control at School Intersections

Everybody's inclination is to assign traffic officers to school intersections. Nearly all parents would like to have their children escorted to and from school by adults, particularly by police officers. One of the principal appeals of some private schools is that the pupils are picked up and delivered at their homes by the school. Most schools also like to be relieved of the responsibility of the children as soon as

they leave school property. Furthermore, many police officers like this duty because it is easy, uncontroversial, and often flattering.

Therefore, everybody's inclination is to assign officers to school crossings. Unquestionably there are places where it is quite necessary; but it is equally true that there is a limit beyond which it is unwise for police departments to attempt to supply this service. A physical limit is reached at the point where men are simply unavailable to meet the demands, but the real problem is one of establishing sensible warrants for this activity which will help to utilize available police strength to the bed advantage of the entire community.

Purpose of Supervising School Crossings.

There are three aspects of crossing streets in which parents and schools are interested: (1) educating and training the child in crossing streets safetly: (2) guarding the child against his own carelessness in crossing; (3) controlling traffic so as to permit safe crossing.

Educating the child in crossing streets safely is today usually begun by parents before the child goes to school. After he starts to school, parents have less and his schoolmates more influence on his behavior. With proper direction by school and parents good habits develop; without follow up by the school some of the caution instilled by parents may be lost. What part should the police play in this? Many officers assigned to school crossings have a natural bent for training and do much good in teaching youngsters how to alert themselves when preparing to cross, to judge traffic and to cross properly. On the other hand, many well-meaning but untrained officers ostentatiously stop vehicles and hurry the children across the street. If anything, this teaches the youngster to watch the officer and run pellmell for the opposite curb when he gives the sign. Such "training" is no help when the children are where there are no officers and often counteracts the efforts of the school to teach children to watch for gaps in traffic and walk to the opposite curb.

Few officers have had training in the educational principles involved in teaching behavior habits and few school systems or police departments are inclined or equipped to give such training to intersection officers. Most police departments are not in a position to assign only specially trained men to school crossings but must send whoever is available. On the other hand, safety educators agree that pupils should be taught early how to cross streets safely and that schools are logical agencies to do this. It follows, therefore, that officers should not be assigned to school crossing for the purpose of teaching children to cross safely, a function which is presumably the responsibility of the school where there should be people especially equipped and trained for this kind of teaching.

However, when officers are assigned to street crossing for other purposes, they should understand and cooperate in the school pedestrian training program so that all efforts will be toward a common goal.

Guarding the child against his own carelessness by watching to see that he does not enter the street unaware of approaching vehicles, misjudge the gaps in traffic, engage in distracting play while crossing and become confused by situations which he has not anticipated can be done by police officers, but by no stretch of the

magination is it possible to visualize enough traffic officers to give protection of his kind to more than a minute proportion of school children.

The best method of seeing that children do not carelessly dash or wander into treet traffic seems to be school safety patrols. These can be stationed at many points ot only adjacent to but at some distance from the schools. Properly taught and supervised as part of the school program, these patrols can successfully watch out for many imes the number of crossing children that police could possibly oversee. By this idespread and continuing supervision, children can be drilled in habits of safety which ecome a pattern of behavior that will safeguard them always, even when they are alone. upplemented by in-school teaching of the principles of safe street crossing, the esults of such a program can not be equaled through any available amount of police ork.

It follows that police officers should not be assigned to school crossings to rotect children from their own carelessness, except as an emergency measure pending he establishment of safety patrols which can do this on a much broader scale or at imes and places where schools could not be expected to assume any responsibility such s crossings to recreational facilities like beaches, and playgrounds.

In places where the authority of police officers is felt necessary to secure bedience by children to the control of safety patrols, it must be assumed that the irection of the patrols by the schools has not developed to the point that it has in ost cummunities so that within the school itself has been built up the necessary iscipline.

Police and traffic engineering departments should be willing to offer the assistance of properly selected and trained personnel to assist schools in establishing patrols. In this the police can capitalize on the esteem and respect of the youthful mind for friendlynofficers of the law and the traffic engineers can suggest pedestrians routes, establish parking regulations, mark crosswalks, and provide warning signs which should be helpful in the program.

Creating Gaps in Traffic

Unfortunately, some schools are located so that pupils must cross traffic of such volume that appropriate gaps for walkers to cross rarely appear. Hazards at school crossings occur principally where children filter through such traffic or in a group see to extend gaps which are too small for the passage of the group. Traffic can be halted to produce gaps by several different means. Three main questions arise in connection with establishing gaps in traffic:

(1) when are natural gaps insufficient
(2) by what means can gaps best be created
(3) for how few children is it practical to undertake to create these gaps?

Natural Gaps in Traffic

If reasonable safety for crossing without control of traffic is to be assured, natural gaps in traffic should be lsufficient for the child or group to walk, not run, from one curg to the other. Observations indicate that elementary school children walk about 3.5 feet per second. Small ones go slower, larger ones faster, but within a range of 3 to 4.5 feet per second, 3.5 seems to be close enough for the purpose.

If the time between gaps averages more than about a minute, children singly or in groups, will lose patience and either start to play, which distracts attention from the problem of crossing and may cause darting into the street, or they"force" gaps too small to permit complete crossing, that is, they filter through traffic. These conditions occur even with school safety patrols.

Large groups of children obviously require longer to cross the street than single children or small groups. Thirty to forty children, as many as can ordinarily be accumulated at one time, will straggle or expand to about 20 feet in crossing. That is, when the first ones are across, the last ones will be 20 feet from the curb.

Based on these characteristics of behavior, it is possible to compute the volume of traffic which will not give natural gaps great enough and frequent enough to permit children to cross without traffic interference. Results of these computations are shown in Exhibit 1 and the method of making them in the appendix. For example, if small groups of children must cross a 40-foot street, natural gaps long enough to permit wqlking clear across will occur on the average of more than one a minute with traffic volumes (total of both directions) up to 500 vehicles per hour. Above that volume, natural gaps will be shorter and less frequent.

Some factor of safety is needed to allow for slower walkers, inability of children to mudge borderline opportunities to cross and other unfavorable conditions. This factor of safety is provided. The whole width of the street is rarely blocked simultaneously so that a child can start across while the opposite side is blocked. The obstructing vehicle will have cleared before there is any conflict with the pedestrian. Hence the actual time available for crossing is greater than that used as a basis for calculation. This is especially true at school crossings because the children cross the street in one direction only during a gap in traffic.

These calculations are not valid if the view of approaching traffic is obstructed so that children cannot perceive the gaps far enough in advance to take advantage of them, or near traffic signals where gaps in traffic may be greater or less than normal. Of course, at signalized intersections, gaps are artifically created.

Standard Rules for Operation of School Safety Patrols have been established by a committee consisting of representatives of the American Automobile Association, National Congress of Parents and Teachers, National Education Association, National Safety Council and U. S. Office of Education. They provide that school children shall not be given the responsibility of controlling traffic but should limit and direct their attention to controlling and supervising pupils. There remains, then,

three major possibilities of traffic control to create artifical gaps when natural ones are insufficient; i.e., traffic signals, police officers, and other authorized adults.

Experience has shown that drivers will respond well to each of these methods if it is properly established. The choice between them therefore becomes one of determining which is the least drain on the taxpayers' pocket. Because of the immense difference between localities in the cost of installing signals, employing patrolmen and other factors, no general rule can be established. Each intersection is an individual problem to be worked out jointly by police, traffic engineers and school authorities. In determining the relative expense of various methods all cost should be computed or estimated and reduced to a unit basis. Exhibit 2, an example of such calculations will serve to show the general method.

Janitors, teachers, firemen, watchmen and others employed part-time for the purpose of controlling traffic at school crossings expect to be compensated for this extra duty if it takes time beyond that covered by their regular pay. These costs must, of course, be included in a computation. Nevertheless, the lowest cost of control is generally that furnished by authorised teachers, janitors, or other persons who normally work near the crossing. Less time is required for them to reach their stations. However, as the distance from the school increases, the travel time of such people increases the cost. Moreoever, they are less acceptable to drivers when the connection with the school is not obvious, or where the traffic volume is exceptionally large. Equipping such people with white belts, special caps or other conspicuous insignia helps drivers to recognize them.

It follows that at locations some distance from the school, particularly where traffic volumes are large, police may be the more desirable and economical means of control. Important factor in the cost of police operations is that of transporting police to and from schools or tying up the police equipment while the men are on school crossing duty and precluding men from other assignments, for half an hour or more to make sure that they will be at the school crossing when needed.

The cost of traffic signals depends much upon the accessibility of electrical energy, availability of mountings, amount of sidewalk or pavement breaking necessary, and other strictly local factors. Substandard signals should never be installed to keep costs down at school crossings any more than maladjusted officers should be assigned there simply to give them something to do. In either case the result may be more rather than less hazard. Since a considerable part of the cost of the signals is in the investment, they may be less economical at those crossings which require control only at one of the four child-use periods during the day.

If signals are used, they should be in operation only when warranted by children crossing or by traffic conditions. Otherwise, drivers waiting at a red light when there is little or no reason for being stopped are tempted to disregard the signal or at least develop contempt for traffic control at that point if not in general. It is customary traffic engineering practice to have the signals show a flashing yellow light by a time control during hours when not wanted. In the vacation months the signal head may be covered by a canvas hood so that it may be turned off without giving the impression that it is out of order. It would be possible to have

he signal changed to and from flashing operation by controls in the school for hat purpose. Signals operated by pedestrian push-button also offer a solution o adapting their operation to needs for it. If this is done only school authorities r safety patrols should operate the buttons or the signals should be arranged to ssume a regular cycle if the button is too frequently pushed; otherwise mischievous children will interfere.

EXHIBIT 2_A

SAMPLE COMPUTATIONS OF COSTS OF CONTROLLING TRAFFIC AT SCHOOL CROSSIN

Intersection of Jefferson and New Jersey requires control for 30 minutes twice per day before opening and 20 minutes twice per day after school closes. See Analysis sheet for warrants.

Control by Police Officer- Data from Traffic Division of Police Dept.
Officer must be taken to location in squad car and returned to station 3 times per day. He will remain on duty through noon hour. Trip is 1.2 miles each way and squad car will average 6 minutes, including running and waiting time.

Officers' pay:	
2.9 hr/day x 180 days/yr at $2500/yr - 2000 hr/yr	$653.00
0.8 hr/day x 180 days/yr at $2500/yr - 2000 hr/yr	180.00
Car cost:	
1.2 mi. x 6 trips x 180 days/yr at $.06/mile	n 78.00
Total cost per year	$911.00

CONTROL BY SIGNAL- Data by Traffic Engineering Bureau.
Four 2-faced signal heads, mountings, controller, time switch and connections installed for operation 4 hours and flashing 20 hours per day 260 days per year. Signal hooded remainder of year.

Depreciation: $2500 - 20 years	$125.00
I$_n$terest: $2500/2 at 2¼%	28.13
Power: 500 watts x 4 hr. - 2,000 watt-hours	
240 watts x 20 hr - 4,800 watt-hours	
Total 6.8 kwh x 260 days at 2¢ kwh	38.00
Mintenance: 4 inspections/yr $2.00 average	8.00
Painting: $20.00 - 4 years	3.00
Hoods: $30.00 - 4 years	5.00
Hoods: $30.00 - 4 years	7.50
Total cost per year	$214.63

EXHIBIT 2-B
SCHOOL CROSSING ANALYSIS

CONTROL REQUIRED Only in Morning

REET CROSSED	Jefferson -W of New Jersey Only 30' wide			
me of Use	8:00-8:30	12:00 12:30	12:45-1:15	3:30-3:50
nutes Per day	30	20	30	20
ildren Crossing	250	240	240	250
hicles Per Hour	350	250	250	200
ntrol Required (From Chart)	Yes	No	No	No
zard Factor (CV/1000	88	...	...	...
tal Hazard Factor				88

CONTROL WARRANTED AT ALL PERIODS

REET CROSSED	New Jersey - N. & S. at Jefferson 60' wide			
me of use	Same	Same	Same	Same
ildren Crossing	190N+50S	182N +48S	182N+48S	190N+50S
hicles Per Hour	500	300	280	270
ntrol Required (From Chart)	Yes	Yes	Yes	Yes
zard Factor (CV/1000)	120	69	64	65
tal Hazard Factor				318

MBINED Total Hazard Factor (at crossings requiring control)		406
arly cost of control (See separate estimates)	Police Officer	$911.
	Traffic Signal	$214.
arly cost per unit hazard by least expensive method		$ 0.07

Except in rural villages, it is folly to assume that because policemen have he authority to direct traffic and often have little else to do at the moment that he cost of police "protection" at school crossings is little or nothing. If more han one or two crossings need control, other police functions will suffer to the xtent that additional men will be needed for them. This is the equivalent of iring police for school crossing control.

OR HOW FEW CHILDREN SHALL TRAFFIC CONTROL BE PROVIDED?

The last and most difficult problem is to determine how many children must se a crossing to make it worth while to create artificial breaks in traffic. No olice department could afford to send an officer out to see that a single child ot safely across a boulevard. Traffic signals would not logically be warranted or this purpose. Mothers, howev er, often drive their children to school to get hem across a main highway or accompany them that far on foot. That the saving f a single life, especially that of a "kiddie" is worth any expense, is the oundest kind of sentiment and if death is inevitable without aid, the whole ommunity rushes eagerly to the rescue. But the natural chances of injury are nly moderate, even if they are continually present, it is hard to maintain such ervor for safety especially when the cost becomes "prohibitive".

This question will porbably always be settled on a relative basis by the ommunities in which it appears. A quiet, well-to-do town with its schools off he main route and little police activity will not hesitate to assign an officer

to a school crossing at a cost to the community of $10.00 per pupil using the crossing per year, even with quite a moderate hazard at that point. On the other hand, in metropolitan areas where most schools are near thoroughfares and the police are admittedly undermanned, it may not be practicable to protect crossings if the cost would be as low as ten cents per pupil per year even with considerable hazard present. The same thing is true with traffic signals. Small communities will and can put them in at intersections for which they would never be considered warranted in big cities.

In every given community, the relative value of traffic control for breating gaps where they are needed at school crossings can be estimated by computing the cost per unit of hazard at the crossing under consideration. For this purpose the unit of hazard may be considered as the qverage number of walkers crossing a street while control is in operation times the average number of thousands of vehicles in both directions per hour. Thus, if 100 children cross a street carrying an average of 1200 vehicles per hour, the total hazard factor will be 120. Dividing the annual cost of controlling this location to give gaps in traffic by the hazard factor will give the cost per unit hazard. If children cross this traffic four times per day, the total hazard will be four times as great provided the number of children and the traffic volume is the same each time. j Locations inexpensively controlled with many children using them will obviously receive first consideration. Those which are expensive to control but have many children crossing may be equal in cost per unit HAZARD TO THOSE with fewer children but less expensive control measures. Last will always be those which are both expensive to control and are used by few children.

Clearly, therefore, advising a community how much of its money it should spend on creating gaps in traffic,for children at school crossings is like advising a family how much of its budget should be for health or recreation or insurance. So much depends upon the relative importance of other demands upon the resources of the family or the community. At best only a guide can be indicated. For this purpose it seems that a hazard factor of 30 is about the smallest which ordinarily justifies even inexpensive control at school crossings. Such a factor would, of course, only justify control on a street without adequate natural gaps in traffic. A hazard factor of 30 represents 30 children crossing a street carrying 1,000 vehicles per hour. Other values for this borderline hazard factor are shown in Exhibit 3.

Naturally, special conditions may make control desirable where it would otherwise not be warranted. For example, obstructions which prevent drivers seeing children and children seeing automobiles may make means of controlling gaps in traffic desirable. At some times and places where children cross streets there are none old enough to provide school safety patrols, hence some arrangement must be made to protect them from their own carelessness. There are a few neighborhoods where, unfortunately, drivers or children are exceptionally lawless and undisciplined so that traffic may require police enforcement as well as direction.

In any city a survey of school crossings at which officers or mothers are assigned to direct traffic or where special traffic control devices have been installed, plus crossings at which there may be need for control can lead to establishment of minimum hazard factor for that particular community which might be higher or lower than general recommendation. For each crossing under consideration, the traffic volume and pedestrian volume, width of street and annual cost of control by various methods should be studied and compared. By this means the locations can be ranked in order of cost per unit hazard.

In any such work questiins will inevitably arise as to what city department hould defray the expense of directing traffic at school crossings where needed. uch accounting problems should not, however, stand in the way of the establishment f the uniform policy throughout the community.

ENERAL CONSIDERATIONS

Extremely heavy volumes of vehicles and school pedestrians will warrant the nstallation of overpasses or pedestrian tunnels as alternatives to traffic control. s in the case of signals, economies in the construction of such facilities should not ob them of their attractiveness and therefore their utility. Overpass and tunnel ught to be the path of least resistance across the street so that supervision which ould oblige children and others to use them will be quite unnecessary.

This may be accomplished by such things as ramps (which will accommodate bicycles s well as pedestrians) instead of stairs, direct connections to school yards or uildings, fences to keep people from the more direct path across the pavement, bundant lighting and good drainage and sanitation.

Any means of controlling traffic may usually be arranged to control an intersection and thus provide gaps in traffic on two streets as cheaply as on one. In act, this is general practice. The total hazard of crossing both streets must herefore be taken into consideration. It follows also that intersections used by a arge number of children will be more likely to warrant control than those used by maller numbers. Careful planning of routes to and from school and the instruction f children and parents in the use of these routes can take advantage of existing points here traffis is controlled by signals or officers and can reduce to a smaller number those hich will require special attention.

The general principles involved also suggest consideration in the location of chool. It would appear advisable to locate schools toward the interior of areas ounded and separated by wide streets carrying heavy traffic so that as many of the upils as possible can reach homes over routes crossing only streets where adequate atural gaps in traffic are provided.

EXHIBIT 3

SAMPLE TRAFFIC CONDITIONS RESULTING IN

HAZARD FACTORS OF 30

elative Hazard or Hazard Factor	Average Number of Children Crossing	Average Vehicles Per Hour Using Street	Maximum Street Width Affording Natural Gaps (feet)	Cost Per Child Per Year at 50¢ Per Hour for Control	Cost per Unit Hazard Per Year
30	30	1000	25	$1.00	$1.00
30	50	600	35	.60	1.00
30	100	300	45	.30	1.00
30	200	150	55	.15	1.00

Costs are computed on the assumption that control will be required for 20 minutes on each of 180 school days yearly while children are crossing or a total yearly cost of $30.00. If control is required four times per day at an average of 20 minutes and with the same volumes of traffic, the cost per child per year will be four times as great but the cost per unit hazard will not change.

APPENDIX

METHOD OF COMPUTING TRAFFIC VOLUME FOR VARIOUS STREET WIDTHS WHEN KNOWN GAPS FOR WALKERS ARE REQUIRED.

Assumptions Based on Observations

1. Average speed of children walking is 3.5 ft/sec.
2. Straggle of a large group is approximately 20 ft.
3. Maximum average time between gaps lwhich will be tolerated is one minute.

Symbols.

V - Volume of traffic in both directions (vehicles per hour)
T - Time required for children to cross street or length of required gap in traffic, (seconds)
N- Average number of vehicles per segment of traffic lasting T seconds.
G - Number of gaps in traffic per hour which exceed T seconds in length.
P - Probability of 0 vehicles appearing in a segment of traffic.
D - Width of street.
e - 2.718, the base for natural logarithms.

Development of the Formula

The time for a child to walk across the street is

$$T = D/3.5$$

This is, therefore, the minimum gap which must be provided on the average at least once every 60 seconds.

If an hour's traffic be divided into segments as long as this required gap of T seconds, the number of such equal segments in an hour will be 3600/T and the average number of vehicles in this segment will be

$$\begin{aligned} N &= V \div 3600/T \\ &= VT/3600 \end{aligned}$$

The probability of any segment having no vehicles in it, that is, the probability that it would be available for children to cross without interference can be computed from Poissons Exponential Series, using 0 for the number of units in the segment.

$$P_o = e^{-m}$$
$$= 2.718^{-VT/3600}$$

The probability multiplied by 100, gives the number of chances in 100, or the percentage of chances, that an T-second segment of traffic of V vehicles per hour would be free from any vehicles. Or , putting it another way, multiplying the probability by the numbef of T-second segments per hour will give the number of gaps per hour of T or more seconds in length. Thus the number of gaps per hour is

$$G = P_o \frac{3600}{T}$$

Substituting for P_o the value previously established,

$$G = 2.718^{-VT/3600} \frac{3600}{T}$$

D[illegible] if the number of gaps must be at least one per minute or 60 per hour,

$$2.718^{-VT/3600} \frac{3600}{T} = 60$$

Transposing and cancelling

$$2.718^{-VT/3600} = \frac{T}{60}$$

Taking the natural logarithms of both sides of the equation

$$-VT/3600 = \log_e T - \log_e 60$$
$$= \log_e T - 4.094$$

Transposing

$VT = 3600\,(4.0$[illegible]$ - \log_e T)$

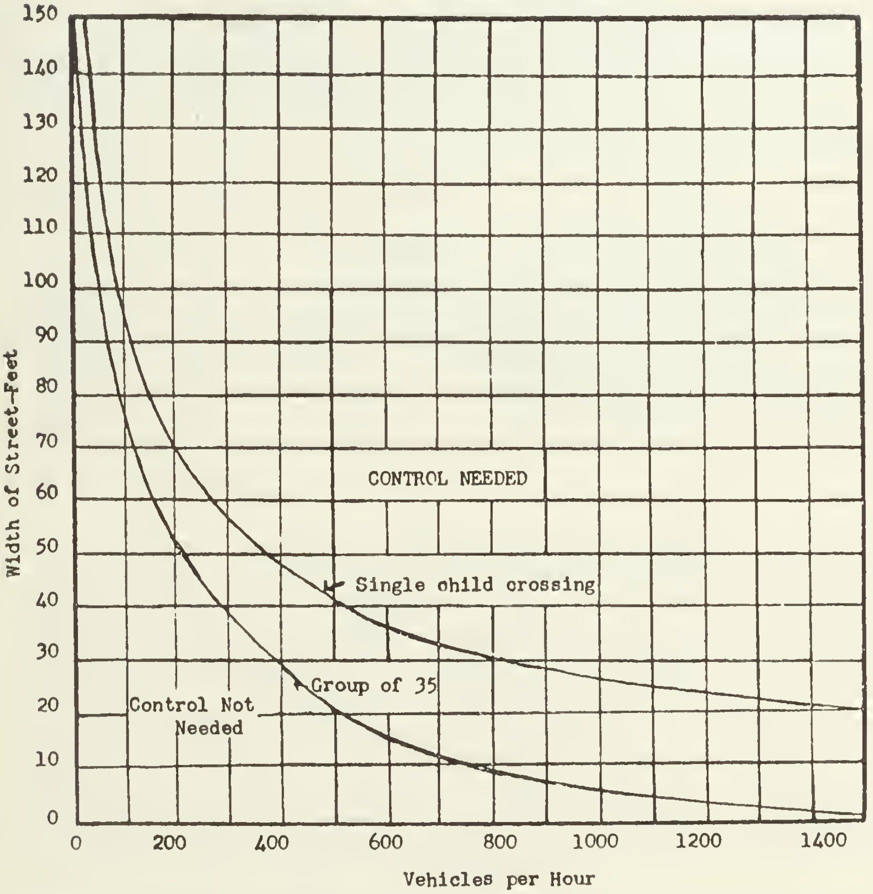
$$V = \frac{3600\,(4.094 - \log_e T)}{T}$$

Substituting for T its value in terms of street width, D/3.5

$$\frac{3600\,(4.094 - \log_e D/3.5}{D/3.5}$$
$$= \underline{3.5 \times 3600\,(4.094 - (\log_e D - \log_e 3.5))}$$

Exhibit 1

REQUIREMENTS FOR TRAFFIC CONTROL AT SCHOOL CROSSINGS



Traffic volumes which, more frequently than an average of one per minute, will provide gaps long enough to allow walking across the street 3.5 feet per second without interference.

FIRST: That applicant is the owner of the property and that any driveway or approach constructed by him is for the bona fide purpose of securing access to his property and not for the purpose of parking or servicing vehicles on the highway right-of-way.

SECOND: That all driveways, approaches or other improvements on the right-of-way, after having been constructed, shall at all times be subject to inspection and the right is reserved to require such changes, additions, repairs and relocations to be made as may at any time be considered necessary to permit the relocation, reconstruction, widening and maintaining of the highway and/or to provide proper and safe protection to life and property on or adjacent to the highway; that the cost of making such changes, additions, repairs and relocations shall be borne by the applicant.

THIRD: That no driveway, approach or other improvement on the right-of-way as an exercise of this permit shall be relocated or its dimensions altered without the written permission of the State Highway Engineer.

FOURTH: That the applicant agrees to hold harmless the Montana Highway Commission and its duly appointed agents and employees against any action for personal injury or property damage sustained by reason of the exercise of this permit.

FIFTH: The location, design, and construction of the driveway or driveways described above shall be in accordance with the following rules and regulations:

(a) The frontage of any parcel or property adjacent to a public highway shall be considered to be confined between lines drawn from the intersection of the property lines with the right-of-way lines of the highway to the roadway surface or to the curbing, if any, and perpendicular to the axis of the highway; or if the axis is a curve, to the center line of the curve; or a combination of the two. Those lines shall be known as boundaries.

(b) No more than one (1) entrance and one (1) exit shall be allowed any parcel of property the frontage of which is less than two hundred (200) feet, except in the instance of commercial establishments providing parking upon the premises, two (2) combined entrances and exits not exceeding thirty (30) feet in width may be allowed. Additional entrances or exits for parcels of property having a frontage in excess of two hundred (200) feet shall be permitted only after showing of actual convenience and necessity. When frontage is fifty (50) feet or less, only a combined entrance and exit is permitted the width of which shall not exceed thirty (30) feet.

(c) The width of any entrance shall not exceed thirty (30) feet measured along the axis of the highway. The width of exits only shall not be over fifteen (15) feet. Area between entrance and exit shall remain unimproved for vehicular travel or parking. This area shall be considered as restricted and may be filled only as hereinafter provided in paragraph (p).

(d) The distance between the inner edges of entrance and exit shall be not less than ten feet where they intersect either the right-of-way line or the road surface.

(e) The grade of entrance and exit shall slope away from the road surface at a rate of not less than 0.02 foot per foot or not more than 0.08 foot per foot for a distance of not less than ten (10) feet; measured from the outer edge of the shoulder; provided this stipulation does not apply when entrance and exit are constructed in accordance with paragraph (k).

(f) No entrance or exit shall be so constructed that any part of such entrance or exit shall be less than ten (10) feet from the boundaries, as defined above, except for returns, the radius of which shall not exceed fifty (50) feet. In urban areas, or where there is a curb and gutter, the distance from the boundary may be five (5) feet.

(g) The construction of parking areas on the highway right-of-way is specifically prohibited. Those places of business requiring parking space for their customers shall provide same on their own premises.

(h) No driveways parallel to the highway shall be constructed on the right-of-way in front of gasoline pumps or other structure requiring an outside drive. Such pumps and structures are to be located a minimum distance of ten (10) feet from the right-of-way line in order that the outside drive shall not encroach on the right-of-way.

(i) Drainage in highway side ditches shall not be altered or impeded and the applicant must provide, at his expense, suitable and approved drainage structures at entrances and exits. The distance between adjacent ends of pipe culverts under entrance and exit shall be not less than ten (10) feet.

(j) When curbing or curb and gutter is to be removed the application shall be accompanied by a certified check, the amount of which shall be equal to two ($2.00) dollars multiplied by the number of linear feet of curbing or curb and gutter to be removed. This guarantee deposit will be returned to the applicant upon satisfactory completion of the work. This provision shall not be exercised when the improvement is located within the corporate limits of a municipality.

(k) When curb and gutter is removed the entrance and exit shall be constructed of concrete and the curbing along the highway shall be returned into the entrance and exit on a radius of not less than three (3) feet nor more than ten (10) feet. The grade of concrete entrances and exits shall conform the grade of sidewalks, if any, and a neat junction between the apron of the entrance and exit and the sidewalk shall be made.

(l) All entrances and exits shall be so located that vehicles approaching or using them will be able to obtain adequate sight distance in both directions along the highway in order to maneuver safely and without interfering with traffic.

(m) The same material shall be used for driveways that is used to surface the roadway unless the character of traffic or adjacent improvements require concrete.

(n) No entrance or exit at the intersection of two state highways shall be within the area between lines drawn perpendicular to the center-line, or axis, of the highway from points on the right-of-way lines a distance of 25 feet from the intersection of said right-of-way lines; provided that this distance may be reduced at the discretion of the State Highway Engineer to 15 feet in case of a highway intersecting a street; further provided that at intersections where additional right-of-way has been secured for the highway back of the prolongation of the normal right-of-way lines in order to provide for the channelization of traffic, or more adequate sight distance, no part of any entrance or exit shall be permitted to encroach on such additional right-of-way. The areas described above shall be considered as restricted areas and may be filled only as hereinafter provided.

(o) No entrance or exit at or near a highway intersection where one or both of the highways has a medial divider or neutral ground, at crossings in esplanade, at bridges or other points of special hazard, as designated by the State Highway Engineer, shall be so located that any part of such entrance or exit, except returns, shall be within the restricted area.

(p) The area betwen entrances and exits, and those portions of the right-of-way which have been defined hereinabove as restricted areas, may be filled in only when the following requirements have been fully complied with.

1. That surface drainage shall be provided so that all surface water on the filled in areas shall be carried away from the highway roadbed in a suitable manner.

2. That the drainage opening underneath the filled in area shall be adequate to carry the water in the highway side ditches.

3. That the entrance and/or exit shall be of concrete with six (6) inch vertical curbs and that the filled in area shall be separated from the highway by a curb and gutter of not less than two (2) feet over-all width and having a six (6) inch vertical curb. The six (6) inch vertical curbs on the driveways shall be returned on a radius of not more than ten (10) feet nor less than three (3) feet to the line of the existing shoulders, where shoulders are wide, but in all cases to a line not less than twenty feet from the center-line of the highway. The curb and gutter separating the filled in area from the highway shall be along the same line. Surface water shall be carried away from the road surface by a suitable and approved means.

4. When a concrete or bituminous surfaced driveway is to be constructed in connection with the filling in of a restricted area the application shall be accompanied by a guarantee deposit in the form of a certified check, the amount of which shall be equal to $2.00 multiplied by the number of square yards of concrete payment or bituminous surfacing to be constructed on the highway right-of-way.

This deposit is to insure the completion of the work authorized by the granting of the application for permit which it accompanies and will be returned upon notice from the ~~district~~ engineer that the work has been satisfactorily completed. division

(q) Data relative to the proposed location, relocation, design and construction of driveways and approaches as may be required by the State Highway Engineer shall be furnished by the applicant free of cost. The applicant shall make any and all changes or additions necessary to make the proposed driveways or approaches satisfactory to the State Highway Engineer.

(r) A guarantee deposit of $10.00 in the form of a certified check shall accompany all applications for permits to construct driveways to commercial establishments. This deposit will be returned upon satisfactory completion of the work authorized. The deposit required by this paragraph shall not be required if a deposit is made under the provisions of paragraph (p) 4.